TITLE OF THE INVENTION

FREQUENCY RESPONSE MEASUREMENT

BACKGROUND OF THE INVENTION

The present invention relates to signal measurement techniques, and more particularly to a method of frequency response measurement of sinusoidal test signals of various frequencies.

It is of interest to use an automated method of measuring the amplitude of sinusoidal test signals of various frequencies of analog and digital signals, such as video signals. Examples include packet or burst amplitudes of a "multi-burst" test signal, such as shown in Fig. 1, or the amplitude of a swept sinusoid signal at a particular frequency. Prior methods of measuring such signals either measure the peak, envelope, curve fitting or other derivative aspect of the amplitude of the multi-bursts. The prior methods for swept sinusoids generally use Fourier Transforms (FT), such as fast Fourier Transforms (FFT), discrete Fourier Transforms (DFT), etc. The peak methods are the most susceptible to errors due to noise and non-linear distortions. The envelope detection methods are less susceptible to noise, but are not robust in the presence of non-linear distortions. The FT methods are useful for relative amplitude measurements of a linear sweep, but do not allow a direct measurement of absolute amplitude for a portion of a sweep or multi-burst at a particular frequency. Also even FT methods optimized for speed, such as FFTs, are relatively computationally expensive if only one or a few frequencies are of interest.

It is desired to have one method of frequency measurement that is robust in the presence of random noise, quantization error, MPEG impairments and other non-linear distortions and interference. Also desired is a method of determining a figure of merit correlated to the probable accuracy of the frequency measurement due to impairments, such as those from MPEG and/or noise. Further it is desired that the frequency measurement work with sinusoidal test signal components, such as bursts, with various time windows – duration and envelope shape, burst spacing, etc. – and with a swept sinusoid. Finally it is desired that the method works with different video standards, such as YPbPr, RGB, high definition, standard definition and computer video, and with variable sample rates not necessarily known *a priori* or related to a clock rate of the corresponding digitized video.

BRIEF SUMMARY OF THE INVENTION

Accordingly the present invention provides a frequency response measurement automatic method for measuring the amplitude of sinusoidal test signals of various frequencies, such as individual packet or burst amplitudes or swept sinusoid amplitude at a particular frequency. The method uses a complex sinusoid window at a particular frequency for correlation with the sinusoidal test signal. The resulting complex correlation magnitude signal is thresholded as a function of a percentage of a maximum complex correlation magnitude. A centroid of the thresholded complex correlation magnitude signal is found, and the complex correlation magnitude at the centroid is the frequency response at the particular frequency.

The objects, advantages and other novel features of the present invention are apparent from the following detailed description when read in conjunction with the appended claims and attached drawing.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

Fig. 1 is a graphic diagram view of a multiple-frequency burst test signal.

Fig. 2 is a logic block diagram view of a frequency response measurement method according to the present invention.

Fig. 3 is a windowed complex sinusoid for use in the frequency response measurement method according to the present invention.

Fig. 4 is a graphic diagram view of the cross-correlation magnitude according to the present invention.

Fig. 5 is a graphic diagram view of the cross-correlation magnitude with relationship to the multiple-frequency burst test signal according to the present invention.

Fig. 6 is a graphic diagram view of a thresholded cross-correlation magnitude according to the present invention.

Fig. 7 is a graphic diagram view of the thresholded cross-magnitude with relationship to the multiple-frequency burst test signal according to the present invention.

Fig. 8 is a graphic diagram view of a marker at the centroid of the thresholded cross-correlation magnitude with relationship to the multiple-frequency burst test signal according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to Fig. 2 windowed sin() and cos() functions **12, 14** representing a complex sinusoid, as shown in Fig. 3, are created at a particular frequency f. A window size if determined based on the particular frequency from which the windowed complex sinusoid is computed. More particularly the window size is a function of the sample rate divided by the particular frequency times a multiplier, which multiplier also is a function of the particular frequency and is selected from the group consisting of a nominal multiplier, 1, 2, 3, etc. $\neq 0$ – if the particular frequency is greater than a first frequency the multiplier is the nominal multiplier, if greater than a second lower frequency the multiplier is 2, if greater than a third yet lower frequency the multiplier is 1. From the window size a window factor is determined which is used to compute the complex sinusoid components of the windowed complex sinusoid.

The windowed complex sinusoid components are input to respective correlators **16, 18** together with an input sinusoidal test signal, either multi-burst or swept sinusoid signal, to produce a complex correlation, the magnitude of which is taken as the square root of the sum of the squares. In other words the windowed complex sinusoid, or each component, slides along the input signal and compared at all points thereof to produce the complex correlation. A maximum value M **22** of the complex correlation C is obtained (see Figs. 4 and 5) when the windowed complex sinusoid aligns with the corresponding burst or swept frequency range of the input signal (see Fig. 6 and 7). The complex correlation C is thresholded **24** using P percent of the

maximum complex correlation M. See Fig. 8. A marker for the frequency *f* is found **26** via a centroid of the thresholded complex correlation magnitude. The frequency response at *f* is the complex correlation magnitude at the marker.

Thus the present invention provides a frequency response measurement that is robust in the presence of noise and other impairments when sweeps, multi-bursts or similar sinusoidal signals are used, is able to qualify the accuracy of the measurement via a correlation coefficient taken as the input channel energy normalized maximum cross-correlation, and finds the frequency of interest among signal components in the signal, i.e., locates the frequency of interest on a video line containing a swept sinusoid.